Study on the Method of Magnetorheological Finishing of Glass Panel of the Inner Screen of Mobile Phone

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Abstract. In view of the problem that there are more scratches on the surface of the glass panel of the inner screen of mobile phone after chemical mechanical polishing(CMP) the glass panel. Three different forms of magnetorheological finishing (MRF) were used to polish the glass panel. The method of MRF and the key process parameters were selected optimally. The results show that MRF based on permanent magnet with static magnetic field can easily create new plastic removal scratches on the surface of glass panel and increase the surface roughness. However, the cluster MRF method based on the rotating magnetic field of permanent magnet relative to the polishing disc can obtain high quality surface of super-smooth and scratch free. In the MRF with dynamic magnetic field based on cluster principle, the surface roughness of the workpiece decreases firstly and then increases with the increase of machining gap. The best polishing effect is obtained, and the surface roughness Ra decreases from 1.16 nm to 0.6 nm when the gap is 1.0 mm. The dynamic effect of magnetic field is more obvious. The surface quality of workpiece is better with the increase of rotating speed of permanent magnet.

Introduction

The inner screen is also called the touch panel. It is an inductive liquid crystal display device which can receive the input signal such as the contact. It mainly consists of the upper and lower glass substrate, the polarizing board and the middle liquid crystal layer. The concrete structure is shown in Fig 1. The manufacturing process of the inner screen includes the forming of glass substrate, the fabrication and combination of thin film transistor(TFT) substrate and color filter(CF) substrate, thinning, grinding and polishing, splitting, etc. The formed glass panel can not meet the requirements of the thickness and toughness of the inner screen, so it is necessary to carry out chemical etching and thinning treatment after the TFT substrate and CF substrate are set up. Chemical etching is using the glass to react with chemical liquid to achieve the role of chemical thinning. There are some surface defects such as uneven surface, scratches, flow line caused by uneven corrosion, Scratch amplification and etching fluid erosion inhomogeneity after chemical etching. The surface defects of the workpiece surface need to be removed by late polishing, and the ultra-smooth surface with high surface smoothness and low surface roughness is obtained.

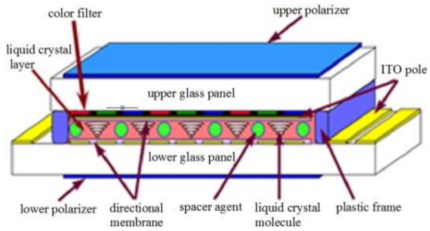


Fig. 1 Cross section chart of the inner screen of mobile phone

At present, traditional polishing machine and CMP machine are generally used to polishing the glass panel. Zhou Yuexuan et al. [1] have used consolidation abrasives to grinding the glass panel of the inner screen to studied the effects of grinding pressure, time, rotational speed and solubility of polishing liquid on the surface roughness and material removal rate. The production efficiency was improved, but the surface roughness was only up to 84.64 nm. Mo Yidong et al. [2] have studied the effects of polishing pressure, rotating speed and polishing fluid flow rate on the TFT-LCD glass substrate by orthogonal experiments. The removal rate of the surface material of the workpiece was 219 nm/min, and the surface roughness Ra was 1.1 nm under the condition of optimal process parameters. Both the traditional polishing technology and CMP technology for the glass panel polishing. Abrasives will produce obvious scratches on the surface of the workpiece, leading to defective rate of the product increase.

MRF is used as a flexible deterministic polishing technology. It is almost no surface and subsurface damage, widely used in the polishing of optical glass, optoelectronic materials, etc [3]. However, the polished "ribbon" of the classic MRF technique is "point" contact with the workpiece surface. In the process of processing, the "dot" can only be scanned along the surface of the workpiece according to certain rules to realize the processing of the whole surface. The polishing efficiency of large-size planar workpiece is very low, and the shape accuracy is not easy to guarantee. For this reason, the research group put forward the cluster MRF to realize the area contact between polishing pads and workpiece surfaces by combining small magnetic bodies to a large-area polishing disk according to cluster principle. By using the proposed method, high machining efficiency can be obtained as well as nanoscale surface roughness [4]. In addition, to improve the cluster MRF, the MR plane finishing method with dynamic magnetic fields formed by eccentric rotation of multi-magnetic poles was put forward to timely modify the polishing pads caused by magnetorheological effect. In the early phase, the electronic strontium titanate (SrTiO) ceramic substrates were polished by using a single magnetic pole, obtained a surface roughness Ra 8 nm smooth surface [5].

Due to the glass panel of the inner screen have Scratches formed by CMP. The polishing of panel glass is studied by using MRF technology which does not produce surface and subsurface damage in this paper. At first, three different kinds of MRF methods were compared. Based on the optimal polishing method, the effects of machining gap and magnetic pole speed on the surface roughness and surface quality of panel glass were investigated by single factor experiments. MRF method and key process parameters are optimized to obtain smooth and scratch-free workpiece surface.

Experimental conditions and evaluation method of machined surface

The polishing material is a long-width 64.5 mm*43.5 mm the inner screen, the original thickness is 390 μm, and the object to be polished is the upper glass panel, and the original surface roughness is Ra 1.16 nm. The inner screen was thinned by chemical etching and surface defects were removed by CMP, but there were still more scratches on the surface of the workpiece, as shown in Fig 5-(a)(b)(c).

First, we explore the best polishing methods for three polishing methods, namely single point MRF with static magnetic field, cluster dynamic pressure MRF with static magnetic fields and cluster MRF with dynamic magnetic fields, under the same process parameters. The experimental setup is shown in Fig 2. The cluster MRF with dynamic magnetic fields method is the best polishing method. After the single factor experiment is carried out on two parameters, the machining gap and the magnetic pole speed, which affect the polishing effect and machining uniformity. The experimental parameters are shown in Table 1. The experimental conditions are as follows: spindle speed of 500 r/min, parabolic disc rotation speed of 60 r/min, processing gap of 1 mm, polishing time of 20 min. The magnetorheological working fluid used in the experiment is made up of deionized water, carbonyl iron powder, cerium oxide abrasive, glycerin and so on.

(a)the single point MRF with static magnetic field device (b) cluster dynamic pressure MRF with static magnetic fields device (c) cluster MRF with dynamic magnetic fields device

Fig 2 three kinds of MRF methods for polishing device.

Table 1 process parameters and factor levels

process parameters	factor levels		
machining gap [mm]	0.8	1.0	1.2
Magnetic pole speed [r/min]	0	60	120

The polished sample is cleaned by the deionized water and dried before and after the test. Mobile phone screen surface divided 6 points as the measurement points. Using the OLS4000 laser scanning confocal microscope to observe the workpiece surface topography. Roughness measurement on the surface and the surface morphology was observed using the ContourGT-X white light interferometer. The measured average value as the surface roughness of the inner screen.

results and discussion

Effect of MRF method on surface quality. Fig 3 is a diagram of the influence of the three MRF methods on the surface roughness Ra. As shown in Fig 3, the surface after through polishing by single point MRF with static magnetic field method, which roughness Ra compared to the original roughness Ra increased up to 1.23 nm. After the cluster dynamic pressure MRF with static magnetic field method polishing. The surface roughness Ra is 0.93 nm. The roughness decreased slightly. The best polishing effect is the cluster MRF with static magnetic field method. The surface roughness Ra reached 0.6 nm after polishing.

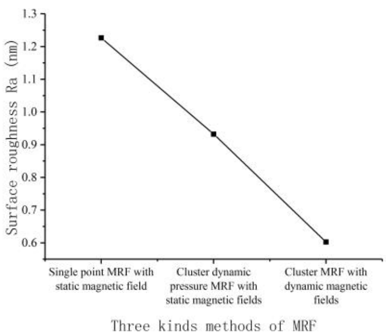
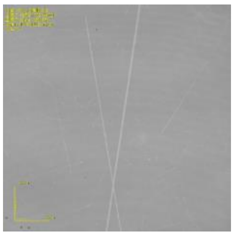
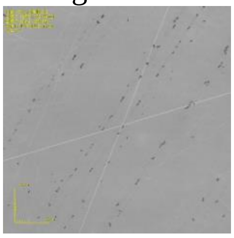
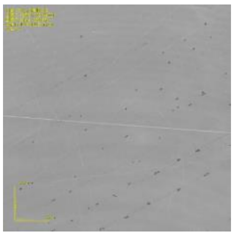


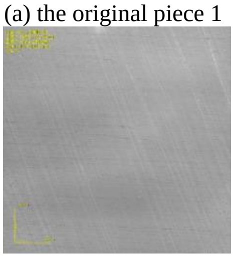
Fig 3 Effect of three MRF methods on the surface roughness of the workpiece

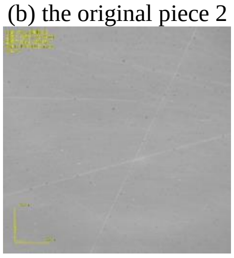
Fig 4 is the surface morphology of the laser scanning confocal microscope obtained from the same position of the three MRF methods before and after polishing. As shown in Fig 4 (a)(b)(c), the surface of the original piece has a deep scratch on the surface after CMP, and the surface of the whole workpiece is covered with small scratches. The main reason is that CMP belongs to free abrasive polishing. There are two body friction and three body friction in the process of polishing, and abrasive is easy to produce brittle scratches on the surface. As shown in Fig 4 (d), the scratch of original surface in the original piece Fig 4 (a) has been completely removed after single point MRF with static magnetic field, but the surface is lined with tiny row of long scratches, and the direction of scratch texture is almost the same. As shown in Fig 4 (e), the scratches on the surface are polished and then shallower, but at the same time produce a small amount of new irregular scratches, after the cluster dynamic pressure MRF with static magnetic field. As shown in Fig 4 (f), the deep scratches and the micro scratches on the surface are almost completely removed, but there are obvious polishing lines on the surface, after the cluster MRF with dynamic magnetic fields. By comparing the three kinds of polishing method for polishing the surface roughness and surface morphology, the glass panel of the inner screen of mobile phone in the cluster MRF with dynamic magnetic fields effect is the best.


(a) the original piece 1


(b) the original piece 2


(c) the original piece 3


(d) single point MRF with static magnetic field


(e) cluster dynamic pressure MRF with static magnetic fields

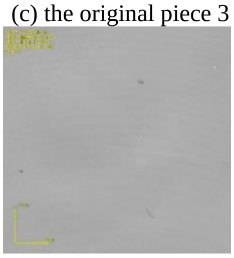
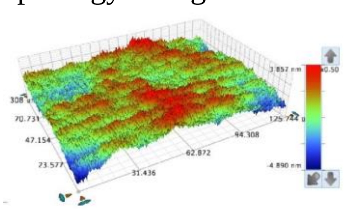
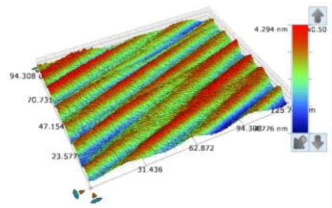
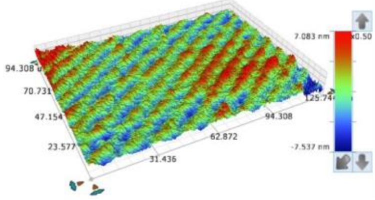

(f) cluster MRF with dynamic magnetic fields

Fig 4 Surface morphology of workpiece with the same position before and after polishing by three MRF methods.

Fig 5 is the surface morphology of the white light interferometer obtained from the original and three MRF methods. As shown in Fig 5 (a), the original surface morphology has no obvious polishing lines, but the distribution of the material has obvious high and low peak values, and the surface roughness is higher. As shown in Fig 5 (b)(c)(d), the surface has a distinct grain and plastic polishing lines after MRF. There is a deep staggered polishing lines on the surface after Single point MRF with static magnetic field method. As shown in Fig 5 (b), after polishing by other two polishing methods, the convex area of the material is preferentially removed, and the surface of the material is smoother. The surface quality is better under the cluster MRF with static magnetic field method, which is consistent with the roughness measurement of Fig 3 and the surface morphology of Fig 4.


(a) the original piece


(b) single point MRF with static magnetic field


(c) cluster dynamic pressure MRF with static magnetic fields

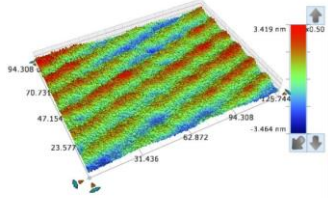

(d) cluster MRF with dynamic magnetic fields

Fig 5 Surface morphology of workpiece before and after polishing by three MRF methods.

Effect of machining gap on surface quality in the cluster MRF with dynamic magnetic fields. The machining gap determines the magnetic field strength of workpiece surface, which directly influence the polishing force based on MRF pad and affecting the polishing effect.

As can be seen from Fig 6, with the increase of machining gap, the surface roughness Ra first decreases and then increases. The processing effect is the best, and the surface roughness Ra decreases from original 1.16 nm to 0.60 nm, when the machining gap is 1.0 mm. In the dynamic magnetic field, the machining gap directly affects the polishing force on the surface of the workpiece and the recovery of the polishing pad. The magnetic field intensity decay exponentially in space, with the increase of the polishing gap. Because of the attenuation of magnetic induction intensity. The working force is gradually weakened. However, when the machining gap is less than the optimum value 1 mm. The abrasive positive stress and shear force of the abrasive particles on the workpiece surface are larger. The material removal rate is strong. It also easy to produce deep removal of grain. Surface roughness will rise. Secondly, the hardness of the polishing pad increases, the magnetorheological particles and abrasive particles can not be fully distributed and accumulated in the MRF, which affects the reorganization of the flexible polishing pad. resulting in the workpiece surface can not be fully processed, affecting the processing effect.

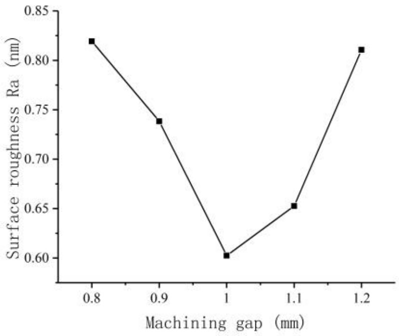


Fig 6 the effect of machining gap on the surface roughness of the workpiece

Influence of magnetic pole rotational speed on the surface quality in the cluster MRF with dynamic magnetic fields. The permanent magnet rotates relative to the polishing disk, which driven the static magnetic field of polishing disk end face into dynamic magnetic field. Thus the performance of the permanent magnet speed change degree of dynamic magnetic field and the polishing pad improvement has important influence. It also affect the iterative update of abrasive and magnetic particles, and further affects the machining the effect of workpiece.

Fig 7 shows the influence diagram of different permanent magnet rotation speed on the surface roughness. In the process of the MRF with dynamic magnetic fields, with the increase of permanent magnet rotation speed, the surface roughness after machining is lower. Hence, it can be seen that the greater the speed of the permanent magnet, the better the processing effect. Because with the increase of the permanent magnet speed, the better the dynamic property of MRF with dynamic magnetic field pad. The transformation degree of magnetic field is further improved. The MRF working fluid in the dynamic magneticrheological effect of continuous formation process of the new polishing pad the abrasive activity becomes high and self sharpening better. It increased the frequency of contact with the surface of the workpiece, thereby polishing effect is better.

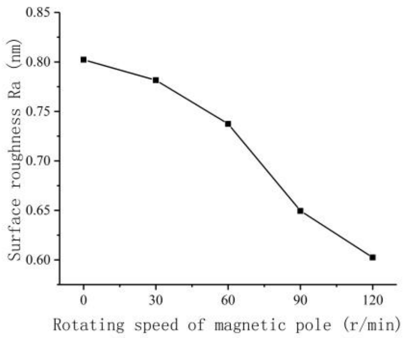


Fig 7 the influence of rotating speed of magnetic pole on the surface roughness of the workpiece

Summary

1)comparing three kinds of MRF methods. The cluster MRF with dynamic magnetic fields method is selected as the best polishing method. The residual scratches of the previous working procedure on the workpiece surface is completely removed on the basis of no new scratch, and the super smooth surface is obtained.
2)the machining gap directly affects the strength of the polishing pad contact with the surface, which causes the change of the polishing pressure on the surface and affects the effect material removal. With the increase of machining gap, the surface roughness first decreases and then increases. The surface roughness Ra 0.6 nm can be obtained when the machining gap is 1.0 mm
3)the rotational speed of the magnetic pole directly affects the real-time recovery of the polishing pad and the renewal of the abrasive particles. As the rotational speed of the rotating magnetic pole increases, the activity of the abrasive particles becomes higher. The self sharpness becomes better, and the surface roughness gradually decreases.

Acknowledgments

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